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Social cognition after head injury: Sarcasm and theory of mind

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Abstract

Closed head injury (CHI) is associated with communication difficulties in everyday social interactions. Previous work has reported impaired comprehension of sarcasm, using sarcastic remarks where the intended meaning is the opposite of the sincere or literal meaning. Participants with CHI in the present study were assessed using two types of sarcastic items, those with a directly opposite meaning and those with an indirect, non-literal but not directly opposite meaning. The CHI group was differentially poorer at comprehending sarcastic versus sincere remarks, although type of sarcastic materials did not influence performance. Errors involved not only literal interpretations, but also incorrect non-literal interpretations. Theory of mind (mentalising) was also assessed by comparing comprehension of human actions with control physical events. The CHI group was selectively impaired on the mentalising component of this task, and mentalising scores correlated with sarcasm comprehension. The implications of the findings for our understanding of impaired sarcastic comprehension after acquired brain injury are discussed.

Keywords: Social cognition; Frontal lobes; Theory of mind; Mentalising; Pragmatic; Sarcasm

1. Introduction

The interpretation of much of what people say and do is affected by the social context in which it takes place, i.e., the setting, the people present, the relationship between them, and their beliefs and intentions. Research to date has shown that processing pragmatic communications involving non-literal meanings such as indirect requests, humour, deception and sarcasm may pose particular difficulties after brain injury, despite intact ability to process syntactic and semantic aspects of language. Ability to interpret pragmatic language appropriately in social interactions is fundamental to successful functioning in many aspects of everyday life, and is commonly disrupted by brain damage. Impairment in processing pragmatic materials including the interpretation of ambiguous advertisements, story vignettes including lies, sarcasm, humour and so on has been reported in adults with right hemisphere lesions (e.g., Brownell, Simpson, Bihrle, Potter, & Gardner, 1990; Winner, Brownell, Happé, Blum, & Pincus, 1998), and more recently in those with frontal lobe lesions and closed head injury (CHI) (e.g., Channon & Crawford, 2000; Pearce, McDonald, & Coltheart, 1998; Shamay, Tomer, & Aharon-Peretz, 2002). In addition to the above studies, which have concentrated on impaired pragmatic language processing in clinical populations where language development was normal until adulthood, pragmatic difficulties have also been described in children after CHI (e.g., Dennis, Purvis, Barnes, Wilkinson, & Winner, 2001) and in neurodevelopmental disorders, particularly autism (e.g., Dennis, Lazenby, & Lockyer, 2001; Ozonoff & Miller, 1996) and schizophrenia (e.g., Corcoran et al., 1995; Mitchley, Barber, Gray, Brooks, & Livingston, 1998). Other neurodevelopmental disorders such as Williams syndrome and Prader–Willi syndrome have also been associated with difficulties in pragmatic language processing (e.g., Sullivan, Winner, & Tager-Flusberg, 2003).

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CHI is of particular interest from the point of view of adult-acquired deficits in social cognition, since it is associated with marked difficulties in social communication, with impaired processing of pragmatic materials despite intact primary language abilities (e.g., Brooks, Campsie, Symington, Beattie, & McKinlay, 1986; McDonald, 2000). Impairment in processing pragmatic meaning appropriately according to the social context has been reported after CHI in adults using a range of materials (e.g., Bara, Tirassa, & Zettin, 1997; McDonald & Pearce, 1996). Studying CHI thus provides an opportunity to examine processes underpinning pragmatic language deficits.

Sarcasm is a common and relatively complex form of pragmatic communication. Varying definitions of sarcasm and irony appear in the literature, beyond the scope of the present discussion; some refer to sarcasm and irony interchangeably, some treat sarcasm as one form of irony, and others separate the two, for instance with the distinction that sarcasm is targeted at a particular victim, whereas irony is not (see, e.g., Gibbs, 2000; Jorgensen, 1996; Katz, 2000; Kreutz & Glucksberg, 1989; McDonald, 1999). In our use of the term 'sarcasm' here, we refer to remarks made with negative or critical intent, where there is an indirect meaning, i.e., a discrepancy between the literal meaning of the words and the social context. Early models of pragmatic language comprehension postulated that literal meanings were automatically processed before indirect meanings could be accessed (e.g., Grice, 1975), based on detecting contradiction between the social context of the remark and the literal meaning. Others have disputed whether literal meanings are necessarily processed and interpreted before non-literal meanings. For instance, Giora (1999) argued that the most salient meaning in the relevant context was processed, whether or not this was the literal meaning. Dews and Winner (1995) suggested that the literal meaning was processed, but not replaced; rather, this literal meaning contributed to the interpretation of the indirect meaning in the social context, for instance by colouring negative meanings so that they are perceived to be less critical. It has also been argued that comprehension is driven by the social context, such that neither the literal nor salient meaning is necessarily processed if a sufficiently rich context cues interpretation of the correct indirect meaning (see, e.g., Gibbs, 2002; for a discussion).

Developmental models of pragmatic comprehension have postulated stages of processing that depend upon the complexity of the materials. The most commonly used form of sarcasm involves reversal of the direct meaning. This type of sarcasm is referred to here as 'direct sarcasm,' and has been labelled differently by different authors; Grice (1989) referred to it as "antiphrastic irony," Dews et al. (1996) as "direct irony," and Bucciarelli, Colle, and Bara (2003) as "simple irony." Sarcastic remarks are also made with more indirect meanings (i.e., different from, but not directly opposite to, the literal meaning), referred to here as "indirect sarcasm"; this type of sarcasm has been labelled "indirect irony" (Dews et al., 1996) or "complex irony" (Bucciarelli et al., 2003). For example, Bosco et al. (2004) gave the following example: "Alex takes out from a toaster two completely burned pieces of toast. Mary arrives and Alex asks with a puzzled expression: 'Am I a good cook?' Mary answers... " 'The best cook in the world!' ("simple irony," referred to here as direct sarcasm) or 'I'll hire you in my restaurant' ("complex irony," referred to here as indirect sarcasm). There is some evidence of developmental stages in the comprehension of these two types of sarcastic remark. For instance, Dews et al. (1996) reported that young children (aged 6–7) did not appreciate the perceived funniness of the more subtle type of indirect sarcasm in the same way as older children (8–9) and adults. Children aged 6–10 have been found to show better comprehension of simpler speech acts including direct versus indirect sarcasm (Bosco and Bucciarelli, reported in Bosco et al., 2004), and a similar pattern was found for children aged 6–8 for direct versus indirect sarcasm where facial and body gestures rather than words were used to indicate sarcasm (Bosco et al., 2004). It is not clear whether the distinction between direct and indirect forms of sarcasm reported in children at different developmental stages applies to adults with acquired brain injury, since comprehension of indirect sarcasm has not been explored with the latter group. There is evidence of impairment in adults with traumatic brain injury in the comprehension of direct sarcastic remarks, compared to sincere, non-sarcastic remarks (McDonald & Pearce, 1996). The present study was designed to compare comprehension of both direct and indirect sarcastic remarks in adults with acquired brain injury after CHI.

Previous work assessing comprehension of direct sarcasm found that CHI was associated with literal errors, and interpreted this as support for the view that the literal meanings of the sarcastic remarks were processed before non-literal meanings (McDonald & Pearce, 1996). If CHI leads to literal errors in interpreting sarcasm, this indicates failure to appreciate the non-literal nature of the communication. However, Gibbs (2002) argued that literal errors in this study were a function of the particular materials used. The sarcastic stimuli consisted of two statements, such as 'Mark: "What a great football game," followed by Wayne: "Sorry I made you come." Yes/no answers were used to assess comprehension. Gibbs pointed out that there was no particular reason to make an inference other than the obvious literal one in relation to the first statement, and that a failure to re-evaluate this when followed by a contradictory statement such as the example above would therefore lead to an erro-

neous literal interpretation. The present study was designed to test whether CHI was associated primarily with literal errors when sarcastic remarks were presented in a more detailed social context, and participants were asked to explain the meaning of the remarks verbally. This permitted us to distinguish between errors arising from failures to recognise non-literal meanings and errors reflecting recognition of a non-literal meaning, but incorrect interpretation of that meaning.

One important factor that may influence ability to comprehend sarcasm is theory of mind or mentalising ability to infer others' beliefs and intentions. Mentalising has been linked in the neuropsychological and neuroimaging literature to the medial frontal lobes (e.g., Gallagher & Frith, 2003; Stuss, Gallup, & Alexander, 2001). First-order mentalising tasks are passed around the age of 4 by typically developing children (e.g., Wimmer & Permer, 1983), and second-order mentalising ability (e.g., A thinks that B thinks that...) develops around the age of 6 (e.g., Perner & Wimmer, 1985). Mentalising skills are thought to develop further with increasing age, involving ability to infer more complex mental states, such as double-bluff, which can be understood at around the age of 8 (Happé, 1994), although there are no widely used tests assessing adult-level mentalising skills. There is evidence linking mentalising ability to sarcasm comprehension (see Creusere, 1999). For instance, second-order mentalising performance has been found to be associated with children's ability to recognise direct sarcasm (e.g., Sullivan, Winner, & Hopfield, 1995; Winner & Leekam, 1991). A similar finding was reported for adults with right hemisphere lesions (Winner et al., 1998). This implies that impaired processing of direct sarcasm after adult-acquired CHI may also be linked to mentalising deficits. It is unclear from the existing literature whether CHI in adults is associated with specific difficulties in mentalising, since performance was found to be intact on a simple first-order mentalising task (Bara et al., 1997) and another study reported difficulties in both mentalising and non-mentalising components of the task (Santoro & Spiers, 1994). Other studies reporting impairment in participants with CHI have used pragmatic language judgement tasks that may be influenced by a range of factors other than mentalising (e.g., Channon & Watts, 2003; Levine, Van Horn, & Curtis, 1993; Milders, Fuchs, & Crawford, 2003). The contribution of mentalising ability was assessed in the present study using materials similar in structure to those devised to assess sarcasm comprehension.

The relationship between mentalising skills and comprehension of indirect sarcasm has not been investigated, to our knowledge. Bosco et al. (2004) imply a central role of mentalising ability in their cognitive model of pragmatic processing, since they contend that the shared belief of the participants in the dialogue is central to comprehension of sarcasm. With respect to the distinction between direct and indirect sarcasm, these authors suggest that direct sarcasm can be understood by a simple inference, that the literal meaning of the remark contrasts with the shared belief that this is not true, and that the opposite meaning can therefore be inferred. They argue that indirect sarcasm is also dependent on the shared belief of the participants, but is differentiated from direct sarcasm by the fact that a longer inferential chain is needed to comprehend the remark; for instance, the example above involves shared knowledge both that Alex is not a good cook, and that cooks in restaurants need to be good, to comprehend the indirect meaning. Translating this into a neuropsychological perspective, it is not clear whether Bosco et al.'s model implicates higher levels of mentalising ability as the key factor mediating ability to comprehend longer inferential chains, or whether other processes such as executive skills are also required.

Another possible factor contributing to deficits in pragmatic processing is impairment in social knowledge relating to everyday pragmatic language usage. Knowledge about when people use sarcasm and other types of pragmatic language evolves through life experience, both from direct interaction with others and indirectly through the media and so on. Social knowledge may be affected directly by acquired brain injury, or the efficiency of strategic access to and usage of such knowledge may be affected (see Channon, 2004). This issue has received little attention to date, and was investigated in the present study.

The focus of the present study was therefore to investigate sarcasm comprehension after acquired brain injury, using both direct sarcasm, already shown to be impaired after CHI, and indirect sarcasm, not previously studied after CHI. The main prediction was that CHI would be associated with selective difficulties in the comprehension of sarcastic versus sincere materials, and that this would be related to mentalising ability and to social knowledge about sarcasm. The study also explored whether comprehension of indirect sarcasm was differentially more impaired than comprehension of direct sarcasm after CHI, since greater difficulty with indirect sarcasm has previously been described in the normal developmental literature. No specific prediction was made with respect to direct versus indirect sarcasm, since no previous work has examined this distinction after adult-acquired injury.

2. Method

2.1. Participants and procedure

Nineteen participants (15m, 4f) who had suffered CHI as a result of a blunt impact were recruited from

a local neurorehabilitation service and from Headway. To be included in the study, participants had to be between 18 and 60 years of age, fluent in English, within the normal range on the Test of Reception of Grammar (TROG) (Bishop, 1989), and to have suffered their injury at least one year ago. Exclusion criteria included alcohol or drug dependence, significant neurological or psychiatric illness before head injury. Participants were also excluded if they had a premorbid verbal IQ score below 80 on the WTAR (Wechsler, 2001), or had expressive or receptive dysphasia. Fifteen of the sample were injured in road traffic accidents, one in a plane accident, one in an assault, and two in falls. Medical information was obtained from hospital or GP records, and also from patients and their relatives. The duration of post-traumatic amnesia, i.e., the time between injury and the reinstatement of continuous memory, was used to determine severity of head injury (Jennett & Teasdale, 1981). This classified 4 of the sample in the 'severe' range of 1–7 days, 10 in the 'very severe' range of 1–4 weeks, and 5 in the 'extremely severe' range of more than 4 weeks (shown in Table 1). Mean duration of time since injury was 9.68 years (*SD* 9.10). Anatomical information about brain damage was limited, since the only scans available had been performed immediately after injury before the final picture of tissue damage emerged, and CT, a far less sensitive methodology for revealing lesions after CHI than MRI, was often used (see Table 1).

Nineteen healthy normal participants (13m, 6f) who matched the CHI group in terms of age, years of education and IQ were also included. The groups did not differ significantly in age (CHI mean 45.74, *SD* 10.03, control mean 44.89, *SD* 9.88), $t(36) = 0.26$, $p = .796$, years of education (CHI mean 13.05, *SD* 1.99, control mean 13.47, *SD* 1.93), $t(36) = 0.66$, $p = .511$, or WTAR Full Scale IQ (CHI mean 103.74, *SD* 9.53, control mean 106.89, *SD* 8.58), $t(36) = 1.07$, $p = .290$. All participants gave written informed consent for the study, and were given breaks between tasks as necessary, to avoid fatigue.

2.2. Sarcasm comprehension task

The sarcasm comprehension task consisted of 18 brief scenarios describing a social context, ending with a single remark by one character. Two different types of sarcastic remark were included: remarks that could be understood by reversal of the direct meaning, and remarks that were indirectly related but could not be solved by direct. These were compared with sincere remarks, where the social context of the story was congruent with the direct meaning of the remark. Examples of the item types are presented below. There were six items in each category. The item sets were matched in length and presented in pseudo-randomised order. To reduce memory load, each story remained on the screen throughout. Participants read the stories, and were asked to explain verbally what

Table 1
Details of injury for the closed head injury (CHI) participants

Case	Age at injury	Years since injury	Severity of post-traumatic amnesia[a]	Scan	Findings
1	27	10	3	CT	R frontal contusion, small L occipital subdural contusion
2	26	13	2	CT	L frontotemporal infarct, low density area in posterior limb of internal capsule
3	35	18	3	CT	L small thalamic haemorrhage and posterior limb of internal capsule
4	18	38	2	MRI	L and R temporal contusions, L parietal subdural
5	18	24	1	MRI	L frontal and periventricular damage
6	28	6	2	CT	Normal
7	39	15	2	CT	Normal, skull fracture
8	53	6	2	CT	R temporal contusion, oedema, skull fracture
9	36	13	3	CT	L frontoparietal contusions, oedema
10	46	10	2	CT	L frontoparietal low attenuation
11	42	3	2	CT	L brainstem contusions
12	58	6	1	CT	Normal
13	46	2	3	CT	R traumatic subarachnoid haemorrhage, L temporal lobe contusions with small subdural haematoma
14	28	7	3	MRI	L frontotemporal, dilatation of K lateral ventricle, evacuation of L subdural haematoma
15	52	1	1	Unknown	Not available
16	31	12	2	CT	L capsule, brainstem
17	33	5	2	CT	L thalamic, internal capsule and superior cerebellar peduncle contusions
18	22	1	2	CT	Normal
19	49	2	1	CT	L hemisphere oedema, narrowing of L lateral ventricle

CT: computed tomography; MRI: magnetic resonance imaging; L: left; R: right.
[a] 1, severe; 2, very severe; 3, extremely severe.

the character meant by their remark. For the verbal responses, a score of two points was given for responses giving a clear correct explanation of the action/event, a score of one point when the answer was not incorrect, but was not adequately explained, and a score of zero points when the answer was incorrect or irrelevant. After participants had read each item and made a verbal response, they were presented with four alternative interpretations, in pseudo-randomised order. These included two correct interpretations (a direct correct interpretation, and a more indirect but still correct interpretation) and two incorrect interpretations (an irrelevant interpretation), and a clearly incorrect interpretation that for the sarcastic (but not the sincere) items provided a salient, literal interpretation of the remark. They were then asked to answer a yes/no non-mentalistic factual inference question, to check understanding of the social context of the story.

2.2.1. Example of a sincere item

'One week, Carla's husband came home late every night. Carla started to worry. At the end of the week, she went to the bank. She found that there was no money in their account. Her husband confessed that he had been gambling and lost a lot of money.

Carla said: ''That was very stupid of you!''
Question 1: What did Carla mean when she said that?'

2.2.2. Example of a direct sarcastic item

'Vicky had bought tickets for a new play at the theatre. One was for herself and the other for her friend Jean. Vicky told Jean the play would be good because her favourite actor was in it. The play turned out to be terrible. They were both disappointed.

Jean said: ''That was a fantastic play you took me to see!''
Question: What did Jean mean when she said that?'

Incorrect non-literal interpretation:

''She was being polite to her friend, because her friend liked it.''

Failure to make non-literal interpretation:

''She was pleased that she was involved in seeing the theatre.''
''She thought it was a fantastic play.''

2.2.3. Example of an indirect sarcastic item

'Liz and her friend often played tennis. Her friend always wanted to be best at everything. One day they were playing tennis in the local park. Liz knew that her friend expected to win the game. However, that day her friend did not win. Liz said:

''I suppose you'll say there's a hole in your racket!''
Question: What did Liz mean when she said that?'

Incorrect non-literal interpretation:

''She let her friend win.''
''You're not as good as me in this game. You're not a match.''

Failure to make non-literal interpretation:

''She thought that because there was a hole in the racket, she was losing all the points.''

2.2.4. Task properties

Data from the healthy control participants were initially examined to establish the properties of the task, using both items correct and means of median time taken to respond. Paired t test comparison of verbal responses for the combined sarcastic items with the sincere items showed significantly higher scores for the sincere than for the sarcastic items (sincere mean 97.37, *SD* 3.98; sarcastic mean 92.11, *SD* 10.03; $p = .014$); time taken did not differ significantly for the item sets (sincere mean 13.92 s, *SD* 5.02; sarcastic mean 14.04 s, *SD* 5.36; $p > .05$). Selection of alternatives did not reveal differences between the item types for correct choices (sincere mean 99.12, *SD* 3.82; indirect mean 97.81, *SD* 3.77) or time taken to respond (sincere mean 7.23 s, *SD* 2.92; sarcastic mean 7.08 s, *SD* 2.40; $p > .05$). The sarcastic items therefore appeared slightly more difficult than the sincere items for the control participants when verbal scores were considered, and were similar to the sincere items on all other indices.

Paired t test comparison of the two types of sarcasm, direct and indirect, showed no significant differences between these for verbal responses in either percentage scores achieved (direct mean 89.04, *SD* 11.13; indirect mean 95.18, *SD* 8.92; $p > .05$) or time taken to respond (direct mean 12.97 s, *SD* 6.56; indirect mean 15.11 s, *SD* 5.11; $p > .05$). When selection of alternatives was examined, there were ceiling effects for correct choices (direct mean 100.00, *SD* .00; indirect mean 95.61, *SD* 7.54); time taken to respond did not differ significantly for the two item types (direct mean 6.88 s, *SD* 2.79; indirect mean 7.29 s, *SD* 2.74; $p > .05$). Overall, there was little evidence that these item types differed in difficulty for the control participants.

2.3. Action comprehension task

This task was similar in structure to the sarcasm comprehension task, and was designed to assess mentalising skills by comparing scenarios ending with human ac-

tions or control physical events rather than with sarcastic or sincere remarks. For the six mentalistic action items, it was necessary to take into account the mental state of the character to interpret the actions. For the six control physical event items, there was always a character in the story, but there was no need to infer a mental state to explain the physical event. Examples of the two types are presented below. As for the sarcasm comprehension task, the item sets were matched in length and presented in pseudo-randomised order. Participants read the stories, which remained on the screen throughout, and were asked to explain verbally why the character carried out the action or why the physical event happened. A score of two points was given for responses giving a clear correct explanation of the action/event, a score of one point when the answer was not incorrect, but was not adequately explained, and a score of zero points when the answer was incorrect or irrelevant. Participants were then presented with four alternative interpretations (in pseudo-randomised order within each item set), two correct and two incorrect, and a yes/no factual inference question, as for the sarcasm comprehension task.

2.3.1. Example of a physical event item

'Kenneth grew vegetables in his garden. There were rows of carrots, potatoes, and cabbages. One morning he went to pick a cabbage. Wire fencing protected the vegetable patch. The metal had rusted and there was a small hole in the fencing. Kenneth walked over to the cabbages.

There were no cabbages left in the patch.
Question: Why were there no cabbages left?'

2.3.2. Example of a mentalistic action item

'Dave wanted to impress his new girlfriend Marie. He was cooking her a meal, but had never cooked before. Marie hoped it would be successful. Dave told her he had spent all day preparing it. When it came out of the oven it was badly burnt. Marie ate all her meal.

Afterwards she took a second helping of the food.
Question: Why did Marie take a second helping?'

2.3.3. Task properties

The properties of the task were initially examined for the healthy control participants, using both items correct and means of median time taken to respond. Paired t test comparison of the mentalistic action versus physical event item types showed no significant differences between these for verbal response scores (mentalistic action mean 96.93, *SD* 4.98; physical event 99.12, *SD* 3.82; $p > .05$) or time taken to respond (mentalistic action mean 10.82 s, *SD* 5.21; physical event mean 9.42 s, *SD* 3.55; $p > .05$). Selection of alternatives did not reveal differences between the item types for correct choices, which were at ceiling (100%) for both mentalistic actions and physical events, or for time taken to respond (mentalistic action mean 5.31 s, *SD* 2.20; physical event mean 5.28 s, *SD* 2.08; $p > .05$). The difficulty of the two types of items therefore appeared similar for the control participants.

2.4. Social usage of sarcasm task

Participants were asked to make ratings on a four-point scale (see below) of how likely it would be for someone to be sarcastic to a range of people. These included three familiar people and three less familiar people (see example below). They were also asked to make ratings on a four-point scale (see below) of how appropriate it would be to use sarcasm in a range of situations. These included three informal situations and three formal situations (see below). These ratings were averaged for the purposes of analysis.

2.4.1. Example of familiar person

How likely, in general, would it be for someone to be sarcastic to the following person?
To a friend

1 = very likely	2 = fairly likely	3 = fairly unlikely	4 = very unlikely

2.4.2. Example of unfamiliar person

How likely, in general, would it be for someone to be sarcastic to the following person?
To a stranger on a train

1 = very likely	2 = fairly likely	3 = fairly unlikely	4 = very unlikely

2.4.3. Example of informal situation

How appropriate, in general, would it be to be sarcastic in the following situation?
At a party

1 = very appropriate	2 = fairly appropriate	3 = fairly inappropriate	4 = very inappropriate

2.4.4. Example of informal situation

How appropriate, in general, would it be to be sarcastic in the following situation?
At a job interview

1 = very appropriate	2 = fairly appropriate	3 = fairly inappropriate	4 = very inappropriate

2.4.5. Task properties

The properties of the task were initially examined for the healthy control participants. Paired t test comparison of the ratings for people showed that they rated the use of sarcasm as significantly more likely for familiar people than for strangers (familiar mean 88.16, *SD* 13.12; strangers 50.00, *SD* 10.76; $p = .0001$). Similarly,

they rated sarcasm to be significantly more appropriate in informal situations compared to formal situations (informal mean 75.44, *SD* 13.46; formal mean 29.82, *SD* 5.06; $p < .05$). The ratings of social usage therefore appeared to differ in the expected direction for the control participants.

3. Results

Mean scores, standard deviations and significance tests for scores on the cognitive tasks are shown in Table 2. A significance level of. 05 was adopted throughout, with adjustment for post hoc tests as specified below.

3.1. Sarcasm comprehension task

3.1.1. Sarcastic versus sincere items

The combined sarcastic items were initially compared with the sincere items for the two groups. ANOVA showed a significant group by item type interaction, $F(1,36) = 10.66$, $p = .002$ and a significant main effect of group, $F(1,36) = 23.00$, $p = .0001$. Post hoc t tests using an adjusted level of significance ($.05/2 = .025$) with

Table 2
Mean scores and standard deviations for the social and non-social measures

	CHI group		Control group	
	Mean	*SD*	Mean	*SD*
Sarcasm comprehension task (%)				
Verbal response score				
Indirect sarcastic items	77.19	16.63	95.18	8.92
Direct sarcastic items	72.81	18.81	89.04	11.13
Sincere items	92.54	9.17	97.37	3.98
Errors for indirect sarcastic responses				
Inadequate responses	19.30	17.80	5.26	9.71
Incorrect non-literal responses	8.77	10.20	1.75	5.26
Failures to make non-literal responses	3.51	6.98	0.88	3.82
Irrelevant responses	0.88	3.82	0.00	0.00
Errors for direct sarcastic responses				
Inadequate responses	24.56	17.89	14.91	16.57
Incorrect non-literal responses	6.14	8.26	2.63	6.24
Failures to make non-literal responses	6.14	9.95	0.88	3.82
Irrelevant responses	2.63	8.36	0.00	0.00
Selection of alternatives				
Indirect sarcastic alternatives	93.86	9.95	95.61	7.54
Direct sarcastic alternatives	92.98	8.45	100.00	0.00
Sincere alternatives	96.49	8.92	99.12	3.82
Factual inference				
Indirect sarcastic items	94.74	9.71	96.49	6.98
Direct sarcastic items	96.49	6.98	96.49	6.98
Sincere items	95.61	7.01	96.49	5.77
Action comprehension task (%)				
Verbal response score				
Mentalistic action items	84.21	16.87	96.93	4.98
Physical control items	96.49	6.40	99.12	3.82
Errors on alternatives				
Action alternatives	96.49	6.98	100.00	0.00
Control alternatives	97.37	8.36	100.00	0.00
Factual inference				
Action items	92.11	12.87	97.37	6.24
Control items	98.25	5.26	99.12	3.82
Social knowledge task (%)[a]				
Likelihood ratings—familiar people	75.46	17.02	88.16	13.12
Likelihood ratings—strangers	53.24	11.83	50.00	10.76
Appropriateness ratings—informal situations	72.69	18.26	75.44	13.46
Appropriateness ratings—formal situations	37.50	11.16	29.82	5.06

[a] $N = 18$ for CHI group.

separate variance estimates showed that the group difference did not reach significance on the sincere items, $t(24.6) = 2.10$, $p = .046$, but that the CHI group had significantly greater difficulties in interpreting the sarcastic items, $t(26.4) = 4.88$, $p = .0001$.

Comparison of the alternatives chosen for the combined sarcastic items versus the sincere items showed no significant group by item type interaction, $F(1,36) = 0.56$, $p = .458$, but the main effect of group was significant, $F(1,36) = 4.36$, $p = .044$, showing the CHI group to score below the control group. Errors in selecting alternatives were relatively rare for both groups. Examination of responses showed that 5.26% of choices for the CHI group involved literal errors on the sarcastic items, and the control group made 2.19%; the CHI group also chose 1.32% irrelevant alternatives; no alternatives of this type were chosen by the control group.

For the factual inference questions, ANOVA for the combined sarcastic items and sincere items showed no significant group by type of item interaction, $F(36) = 0.05$, $p = .817$, nor effect of group, $F(36) = 0.73$, $p = .400$.

3.1.2. Direct versus indirect sarcastic items

The CHI and control groups were then compared on the direct and indirect sarcastic item types. ANOVA for the verbal interpretation scores showed no significant group by item type interaction, $F(1,36) = 0.08$, $p = .779$, but there was a significant effect of group, $F(1,36) = 23.84$, $p = .0001$, showing the CHI participants to score below the control group.

All incorrect answers scoring 0 points were categorised for the direct and indirect sarcastic items to examine the types of mistakes they were making (see Table 2). The remaining errors (awarded 1 point) were those in which the verbal responses were not incorrect, but were not explained in sufficient detail to score fully. Three types of errors scoring 0 points were identified: incorrect non-literal interpretations that wrongly interpreted the meaning of the remark; failures to make non-literal interpretations, interpreting the remark literally; and irrelevant answers. ANOVA comparing the groups in the number of incorrect non-literal interpretations for the direct and indirect sarcastic items showed no significant group by item type interaction, $F(1,36) = 0.98$, $p = .329$, but there was a significant effect of group, $F(1,36) = 8.82$, $p = .005$, showing the CHI participants to score below the control group. Similarly for the number of failures to make non-literal interpretations, there was no significant group by item type interaction, $F(1,36) = 1.00$, $p = .324$, but there was a significant effect of group, $F(1,36) = 5.32$, $p = .027$, again showing the CHI participants to score below the control group. There were no irrelevant responses for the control group for either the direct or indirect sarcastic items, and only a few for the CHI group. Examples of errors involving incorrect non-literal responses and failures to make non-literal interpretations are shown Section 2.

When selection of alternatives was examined for the direct and indirect sarcastic items, ANOVA showed no significant group by item type interaction, $F(1,36) = 2.70$, $p = .109$, but there was a significant effect of group showing the CHI group to score below the controls, $F(1,36) = 5.63$, $p = .023$.

3.2. Action comprehension task

3.2.1. Group comparison of mentalistic actions versus physical event items

The CHI and control groups were compared using ANOVA to examine verbal responses on the task across the two item types (mentalistic action or physical event). This showed a significant group by condition interaction, $F(1,36) = 6.56$, $p = .015$, and there was a significant main effect of group, $F(1,36) = 10.29$, $p = .003$. Post hoc t tests using an adjusted level of significance ($.05/2 = .025$) with separate variance estimates showed that the groups did not differ significantly on the physical events, $t(29.4) = 1.54$, $p = .135$, but that the CHI group had significantly greater difficulties in interpreting the mentalistic actions, $t(21.1) = 3.15$, $p = .005$.

Selection of alternatives was also examined for the two conditions. Two of the alternative responses were correct, and two were incorrect. The control group was found to be at ceiling on both the mentalistic actions and physical events. Seventeen out of 19 CHI participants also performed at ceiling on the control physical event items and 15 out of 19 CHI participants performed at ceiling on the mentalistic action items (see Table 2). Thus, there was little evidence of difficulties for the CHI group when they were offered choices including correct alternatives. For the factual inference questions, ANOVA showed no significant group by type of item interaction, $F(36) = 1.67$, $p = .205$, nor effect of group, $F(36) = 2.61$, $p = .115$.

3.3. Social usage of sarcasm task

For the likeliness and appropriateness ratings, ANOVA showed no significant group by type of rating by formality (familiar/informal versus stranger/formal) interaction, $F(1,35) = 0.71$, $p = .407$. There was a significant group by type of rating interaction, $F(1,35) = 5.29$, $p = .028$, and also a significant group by formality interaction, $F(1,35) = 5.54$, $p = .024$; the effect of group was not significant ($p = .634$). Post hoc t tests using an adjusted significance level ($.05/4 = .0125$) examining the four sets of ratings individually showed that the CHI group tended to judge sarcasm less likely than the control group with familiar people, $t(35) = 2.55$, $p = .015$, but not with strangers, $t(35) = 0.87$, $p = .389$; and that they

tended to judge it more appropriate in formal situations, $t(23.42) = 2.67$, $p = .014$, but not in informal situations, $t(31.12) = 0.52$, $p = .607$.

3.4. Relationship between sarcasm tasks and other measures

For the CHI group, Pearson product moment correlations were carried out to investigate the relationship between sarcasm comprehension scores and performance on the mentalistic and social usage measures. There was a significant correlation between sarcasm comprehension scores and mentalistic action comprehension scores, $r = .51$, $p = .026$, but not with physical event comprehension scores, $r = .24$, $p = .318$. The correlations between sarcasm comprehension scores and the social usage task were not significant for difference ratings either for familiar/unfamiliar people, $r = .24$, $p = .338$, or for formal/informal places, $r = .04$, $p = .875$. Correlations for sarcasm comprehension with age at injury, years since injury, and severity of severity of injury as defined by classification of post-traumatic amnesia were not significant.

4. Discussion

The main prediction, that CHI would be linked to difficulties in interpreting sarcastic versus sincere remarks, was confirmed. Moreover, their difficulties in processing sarcasm were related to mentalising abilities, but not to social knowledge. No significant differences were found for comprehension of direct versus indirect sarcasm. Examination of errors showed that the CHI participants rarely made literal errors in processing sarcasm; they more often gave incorrect non-literal interpretations. Inferences about localisation of damage underpinning any deficits cannot of course be drawn from the present data. Frontal lobe dysfunction is assumed to be the main mechanism underlying poor performance, since damage to the orbital and lateral frontal lobes typically occurs after injuries of this nature, regardless of the particular site of impact (Ommaya, Grubb, & Naumann, 1971), although other factors including right hemisphere damage or diffuse axonal injury could of course play a part.

Initial comparison of verbal scores for the sarcastic and sincere remarks showed that the sarcastic remarks were slightly more difficult than the sincere remarks for the control group, who were close to ceiling level for the sincere items when verbal interpretation scores were considered, although no differences were found in response times or scores for selection between alternatives. The type of measure used to assess performance is clearly a factor, since only the verbal response scores were sensitive to any differences between the sarcastic and sincere materials. Studies using only measures such as selection between alternatives, ratings or yes/no questions may not detect subtle differences in processing sarcastic versus sincere materials. Moreover, when verbal response measures are considered, some studies have shown that sarcasm lends itself to a variety of interpretations, even amongst normal adults (McDonald, 1999).

Comparison of the CHI and control groups on the sarcastic versus sincere items showed that the CHI group was differentially impaired on the sarcastic items relative to controls. This is consistent with previous findings in adults after CHI using shorter direct sarcastic items (McDonald & Pearce, 1996). CHI participants in the present study also differed marginally from the control group in processing sincere remarks. This might reflect slight pragmatic difficulties in determining whether the sincere meanings were intended in the social context of the story, since even remarks that are meant sincerely may be open to a degree of interpretation, especially since the sincere items were presented mixed in with sarcastic remarks that were not intended sincerely. There might also minor difficulties in other cognitive domains not related to pragmatic language processing such as syntactic or semantic language, long-term memory or visuoperceptual skills. However, dysphasic patients were excluded from the study, and a comprehension screening test was used; the memory demands of the task were minimised by leaving the relevant materials on display throughout; and all participants were able to read the verbal materials.

One aim of the present study was to elucidate the nature of the errors made by adult CHI participants in processing sarcastic material. McDonald and Pearce (1996) described only literal errors in their CHI participants in response to direct sarcasm. However, Gibbs (2002) asserted that any errors on these materials were inevitably literal in nature, since the nature of the task precluded other types of errors. Examination of errors on our more complex test materials in the present study showed that only a small proportion of the errors made by the CHI group reflected literal, sincere interpretations. More commonly, there was evidence that the non-literal nature of the communication had been detected, but that interpretation of the precise non-literal meaning was limited or incorrect. Although rare, literal errors were more common for the CHI group than for controls when asked to explain the meanings of the sarcastic remarks. For instance, literal interpretations of the direct sarcastic example shown in Methods above relating to the disappointing theatre play included "She thought it was a fantastic play." Literal interpretations of the indirect sarcastic example relating to the girl who wanted to watch the horror film included "She thought her mum would prefer her to play with her dolls." As mentioned above, these literal errors were less frequent

than errors that did show a grasp of the non-literal nature of the communication, but were nevertheless either clearly incorrect or inadequate to score full credit. For instance, incorrect non-literal interpretations of direct sarcastic remarks included "She was being polite to her friend because her friend liked it" for the theatre play item. Incorrect non-literal interpretations for the indirect sarcastic remarks included "She was joking with her mother; she has to find something else to do" for the horror film item. The findings therefore suggest that adult CHI participants are often able to recognise that a meaning is non-literal, although they do not always arrive at a correct interpretation of these.

Comprehension of the remarks was also examined by asking participants to choose from alternative meanings supplied to them, removing the need to generate appropriate interpretations. In this component of the task the CHI group performed slightly below the control group, who were around ceiling levels, but nevertheless showed few difficulties in selecting appropriate sarcastic or sincere alternatives. If participants entertained a literal hypothesis as to the meaning, they should have endorsed the literal alternative. However, literal errors were rare, consistent with the above findings from the free verbal responses that participants in both groups most commonly understood that the communication was non-literal, even if the precise meaning eluded them initially. By contrast, recent work (Channon et al., in preparation) found that the errors made by young children presented with alternative literal and non-literal interpretations of sarcastic remarks were most commonly literal in nature. This highlights potential differences between pragmatic language comprehension failure resulting from adult-acquired impairment and that attributable to developmental immaturity.

Mentalising skills were investigated in the present study using a task similar in structure to the sarcasm comprehension task. The findings revealed selective impairment in the CHI group when asked to explain human actions compared to control physical events. Examples of errors for the action item involving the girlfriend eating a second helping of the burnt meal her boyfriend cooked included "She likes burnt food" and "Probably because she was starving". Responses such as these were judged to demonstrate incorrect or inadequate appreciation of the mental state of the protagonist. There were also minor differences when participants were asked to select amongst alternative explanations for the actions/events, since the control group but not the CHI group performed at ceiling on both item types. This is consistent with previous findings in CHI using higher-level tasks that involved both mentalising and pragmatic language processing (e.g., Channon & Watts, 2003; Levine et al., 1993; Milders et al., 2003). Since impaired mentalising is likely to contribute to difficulties in the processing of sarcastic materials, the relationship between this and sarcasm comprehension was examined using correlational analysis. This cannot of course determine causal relationships, and must be treated with caution particularly in studies with small sample sizes. Nevertheless, the findings did suggest a relationship with mentalising, since performance on the human action comprehension items, but not the control physical event items, correlated significantly with sarcasm comprehension. The sarcasm comprehension items were similar in structure to both the action comprehension and physical event items, so this alone does not appear sufficient to account for the correlation only with the mentalistic action items. The action and event items differed primarily in the nature of the inferences required to solve them, since the action items involved understanding of people's mental states. These findings are consistent with those of several previous studies that have linked mentalising ability to sarcasm comprehension in children (Sullivan et al., 1995; Winner & Leekam, 1991) and in adults with right hemisphere lesions (Winner et al., 1998). Moreover, McDonald (2000) reported that patients with traumatic brain injury could understand direct sarcastic remarks when the reversal of meaning involved only factual information, such as: 'Tom: "That's a big dog." Monica: "Yes, it's a miniature poodle,"' but not direct sarcastic remarks involving mentalistic concepts, such as 'Mark: "What a great football game," followed by Wayne: "Sorry I made you come."'

Although the contribution of mentalising skills has been considered in the present study, there are other possible contributory factors including executive skills, linked primarily to lateral prefrontal networks. Some previous studies have examined the relationship between executive skills and pragmatic language processing in patients with CHI (see Body, Perkins, & McDonald, 1999; for a review). For instance, tests including the Wisconsin card-sorting test and Trail-making test have shown correlations with performance on pragmatic measures including comprehension of sarcasm and ambiguity (e.g., McDonald & Pearce, 1996; Pearce et al., 1998). Thus, there may be multiple routes to impaired processing of sarcastic materials after CHI, including deficient mentalising (theory of mind) abilities or executive skills (see Martin & McDonald, 2003; for a discussion).

The present study also explored knowledge relating to social usage of sarcasm as a possible contributory factor in pragmatic comprehension. The CHI group appeared less aware than the control group of differentiations between familiar/informal and unfamiliar/formal situations and people in the everyday usage of sarcasm. Since the groups were matched in age, IQ and education, and CHI was adult-acquired in all cases, it seems improbable that these differences existed prior to the brain injury. The contribution of social knowledge to pragmatic processing depends both on the quality of

the available knowledge itself, and the extent to which it can be readily identified and accessed online when needed. Impaired performance in the CHI group may reflect some loss of social knowledge, and/or reduced efficiency in making adequate use of such knowledge to guide performance as a result of deficient strategic memory search. However, examination of the correlations with sarcasm comprehension scores for the CHI group did not correlate significantly with knowledge of social usage of sarcasm. This showed no evidence of a direct link between impairments in processing sarcastic material and social knowledge. However, the task used here to evaluate social knowledge may have been inadequate to capture the extent of any difficulties experienced by the CHI participants.

The study also investigated whether the CHI group showed greater difficulty understanding indirect compared to direct sarcastic remarks. Previous work has found evidence of differences in comprehension of these two types of sarcasm in typically developing children aged 6 or above (Bosco et al., 2004). However, in contrast with this, the findings from the present study suggested direct and indirect sarcasm to be similarly impaired after CHI. Taken together with the findings described above relating to the nature of the errors made by CHI participants, this suggests that sarcasm processing deficits after adult-acquired brain injury cannot be modelled on stages derived from developmental data. Greater difficulty in processing indirect versus direct sarcasm in children may be related to their evolving mentalising abilities. Mentalising difficulties acquired in adulthood after attaining an adult level of skill are unlikely to resemble those of children who have not reached the full adult level of development. An explanation for the lack of difference between the two types of sarcasm in the present study could be derived from Gibbs' (2002) theory of sarcasm processing, which contends that comprehension is guided by the social context. On this assumption, given a sufficiently rich context, a listener would not necessarily be sensitive to the differences between direct and indirect sarcasm. The use of much briefer contexts than those employed in the present study may produce differences between direct and indirect sarcasm in adults. However, losing the detailed story contexts would reduce the ecological validity of the task, since everyday social interaction does not take place in a vacuum.

In conclusion, CHI participants in the present study showed impaired ability to comprehend sarcastic material, in line with previous work, although type of sarcastic materials did not influence performance. Our findings revealed that errors in processing sarcasm are not always literal in nature, but often reflect incorrect or inadequate non-literal processing. CHI participants frequently showed some appreciation of the non-literal nature of the sarcastic communications, but this in itself was not necessarily sufficient to achieve correct interpretations. As has previously been reported for other populations, there was evidence of an association between mentalising skills and sarcasm comprehension, suggesting mentalising to be a route to impairment after brain injury. It is of course necessary to bear in mind that CHI is likely to reflect heterogeneous routes to impairment in pragmatic language processing, since the severity and extent of any impairments in potential constituent skills including mentalising, social knowledge and executive skills may vary substantially between individuals. Future work needs to address each of these domains to extend our knowledge of sarcasm comprehension.

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